



The Moscovиense Basin

A Microcosm of Crustal Compositional Diversity

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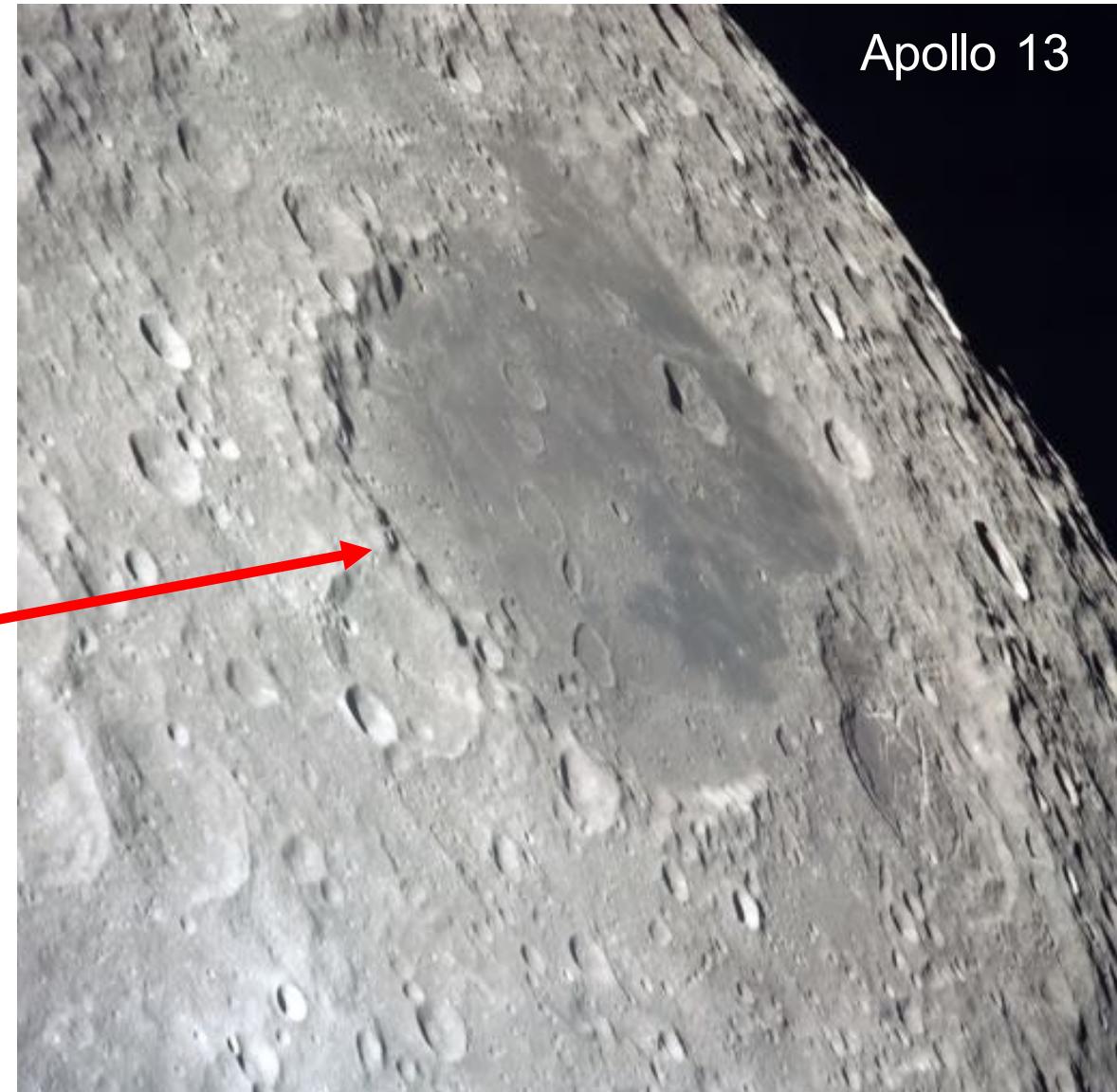
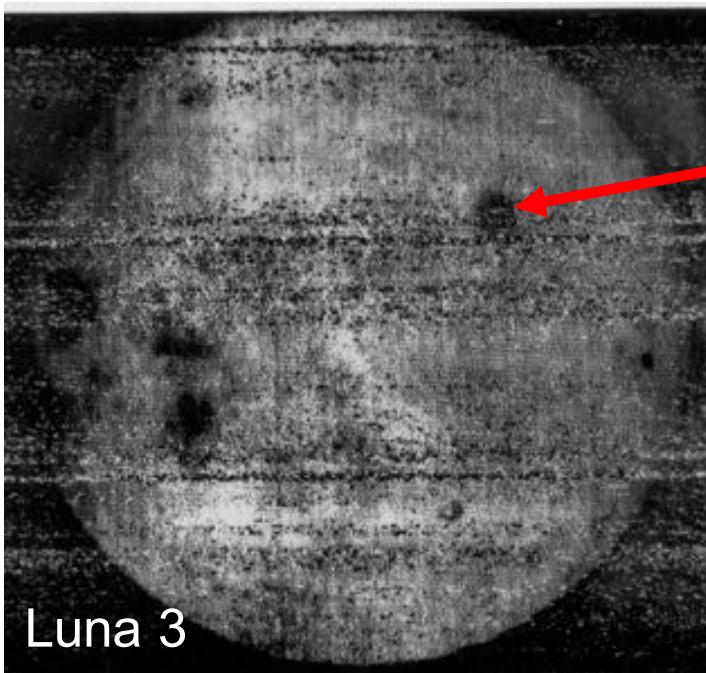
T.D. Glotch, Stony Brook Univ.

Lunar Science for Landed Mission Workshop
NASA Ames Research Center



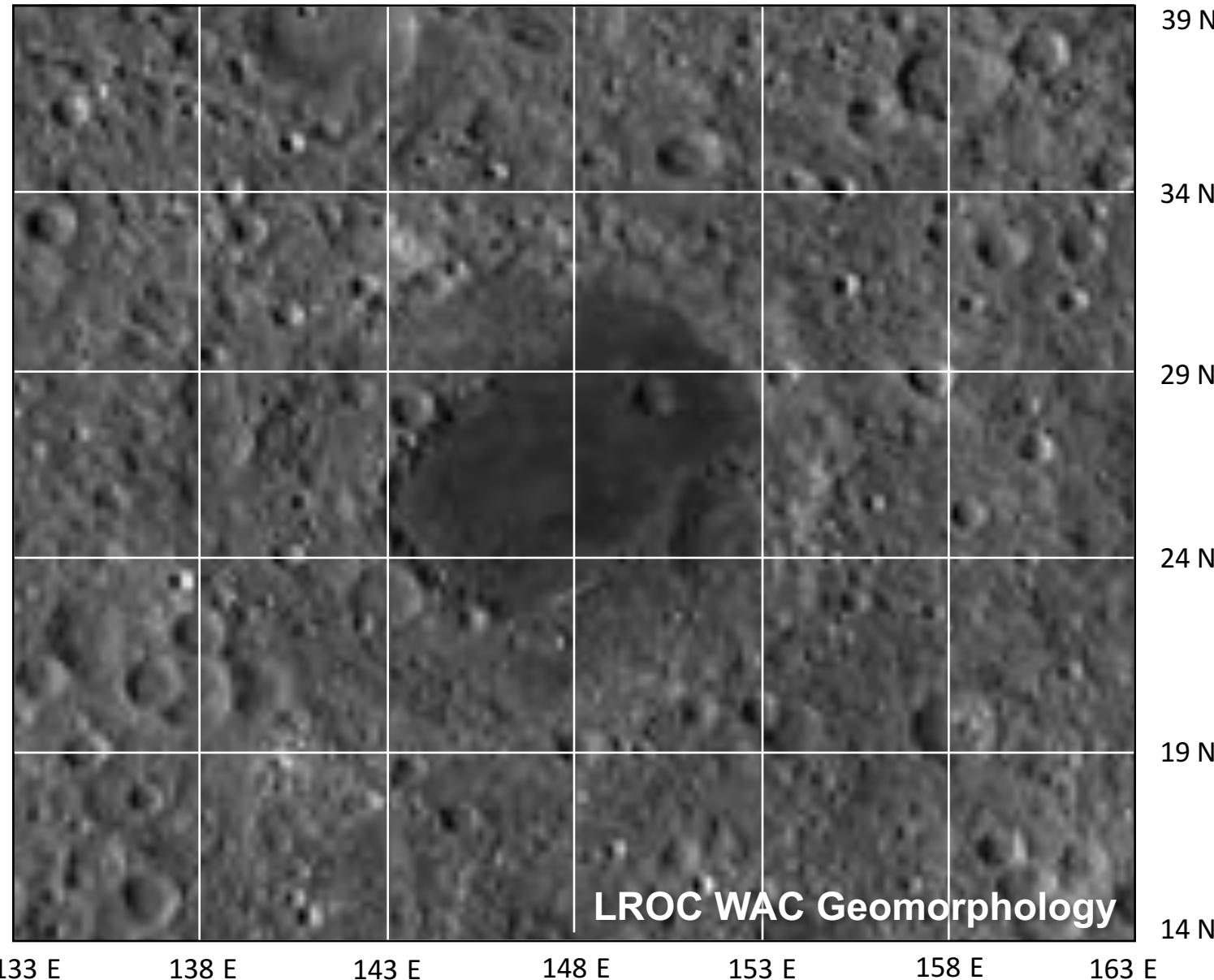
Why Moscoviense is So Awesome

- Unique, large multi-ring basin
- Excellent crustal compositional diversity
- Far side Mare Volcanism
- Even has swirls!



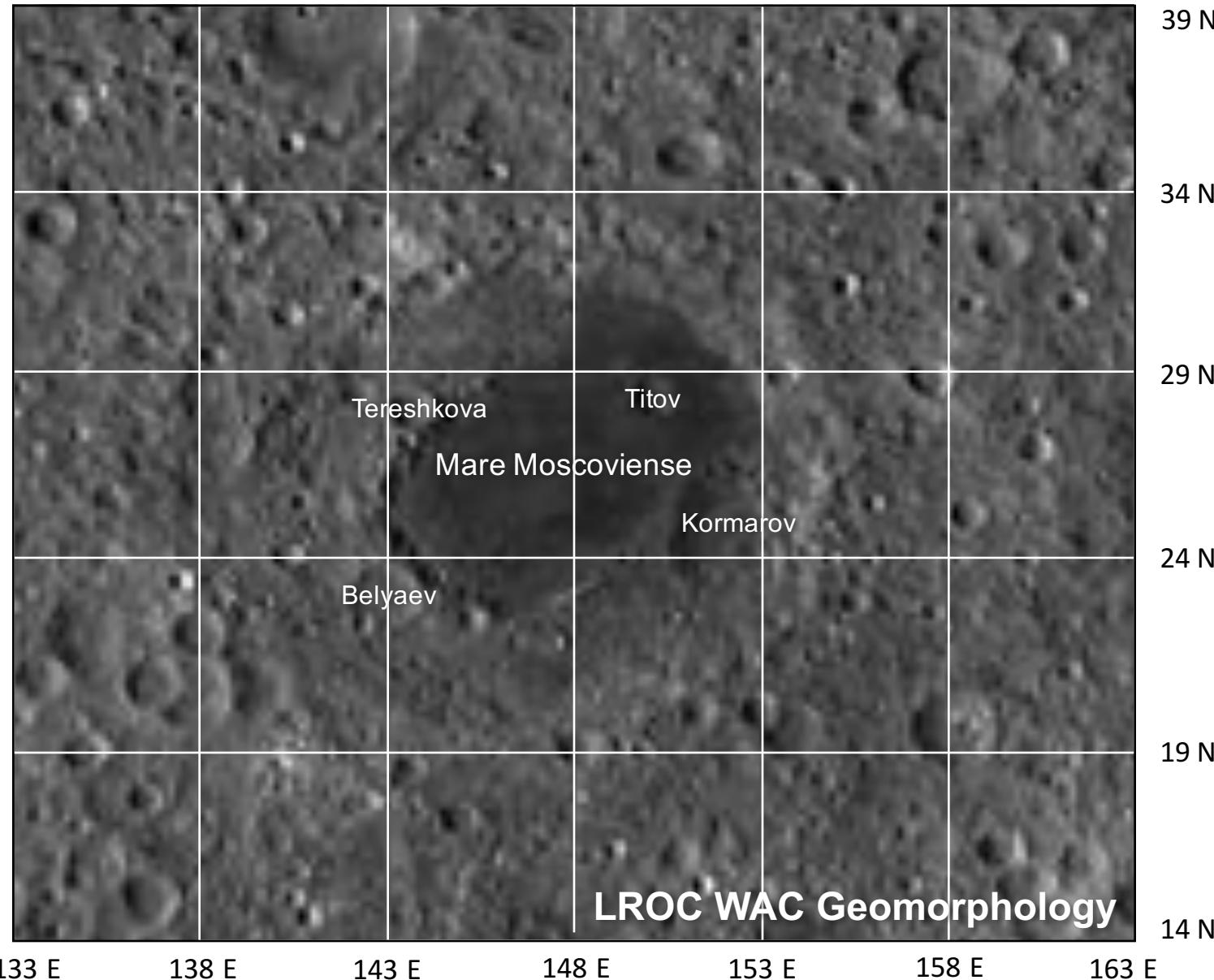
Multi-ring Impact Basin

- Nectarian in age, 3.85-3.92 Ga (Wilhelms et al., 1987)
- Various ring identifications
 - 205 / 410 / 700 km (Wood and Head, 1976)
 - 140 / 220 / 300 / 420 / 630 km (Pike and Spudis, 1987)
 - 210 / 445 km (Wilhelms et al., 1987)
 - 185 / 430 / 659 km (Thaisen et al., 2011)
- Elongated basin floor
- Non-concentric basin rings
- Discontinuous Ejecta
- Thinnest crust on the Moon, in a relatively thick crust terrain
- Gravity Anomaly
- Mare Deposits / Pyroclastics



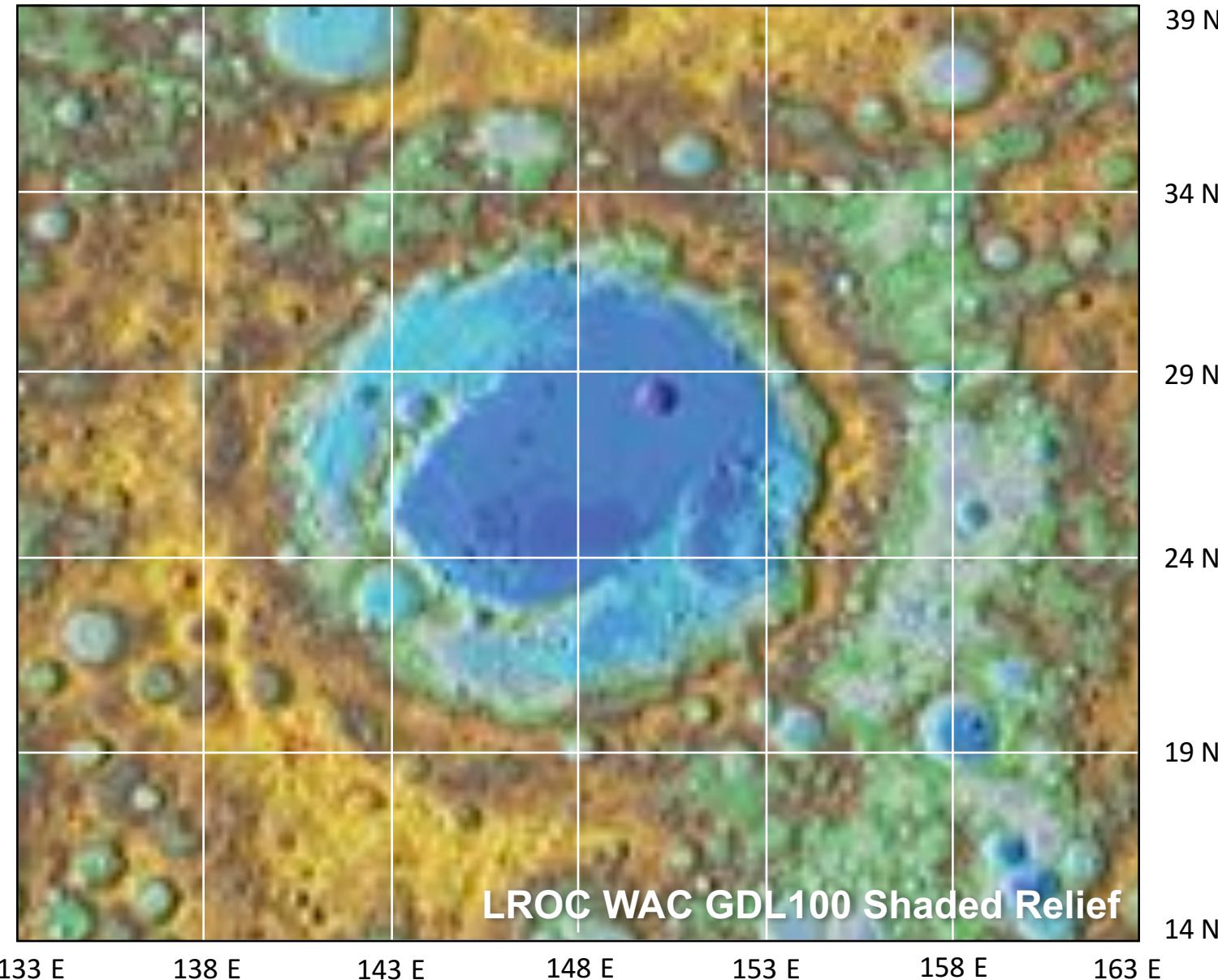
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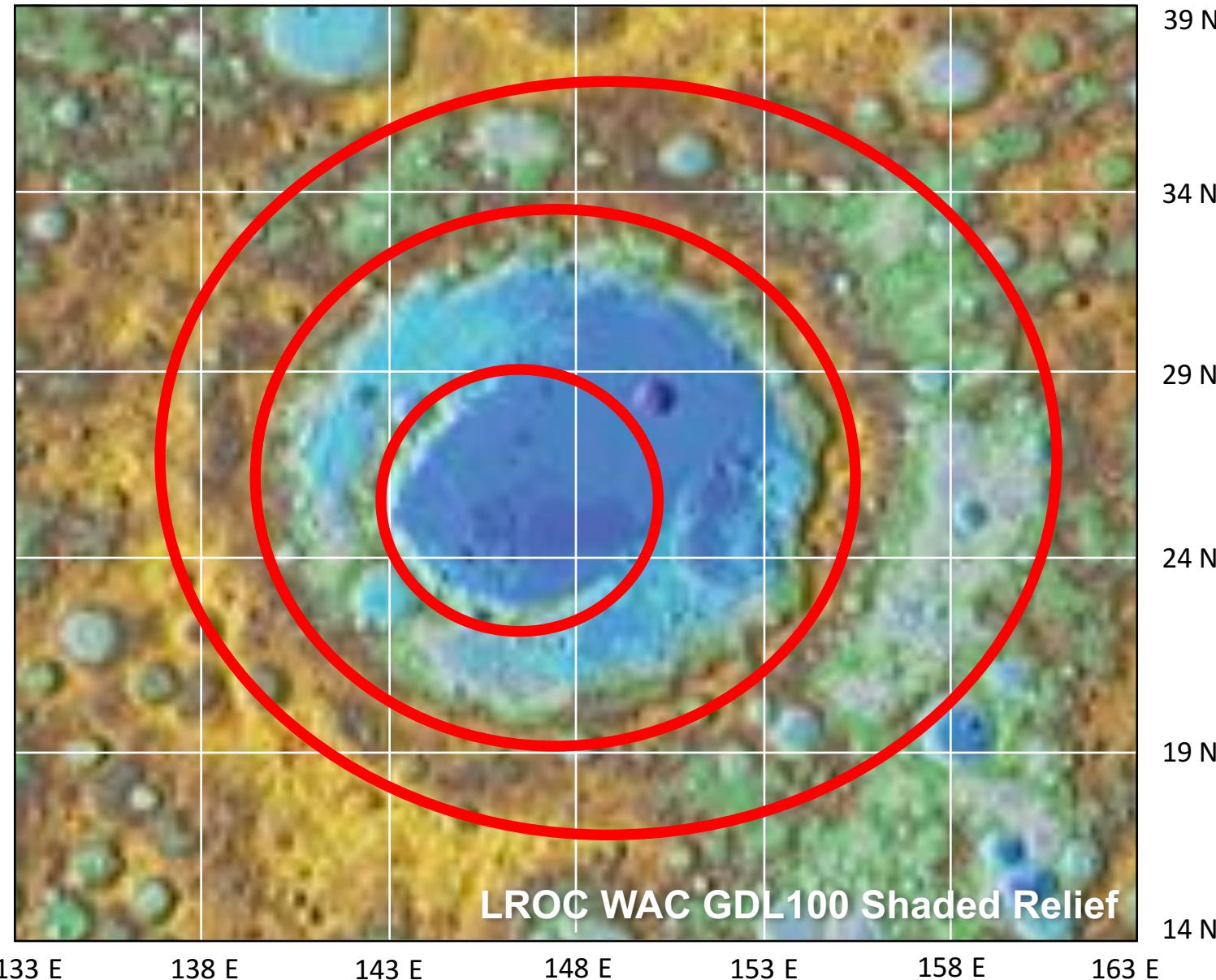
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Multi-ring Impact Basin

Wieczorek et al., 2013

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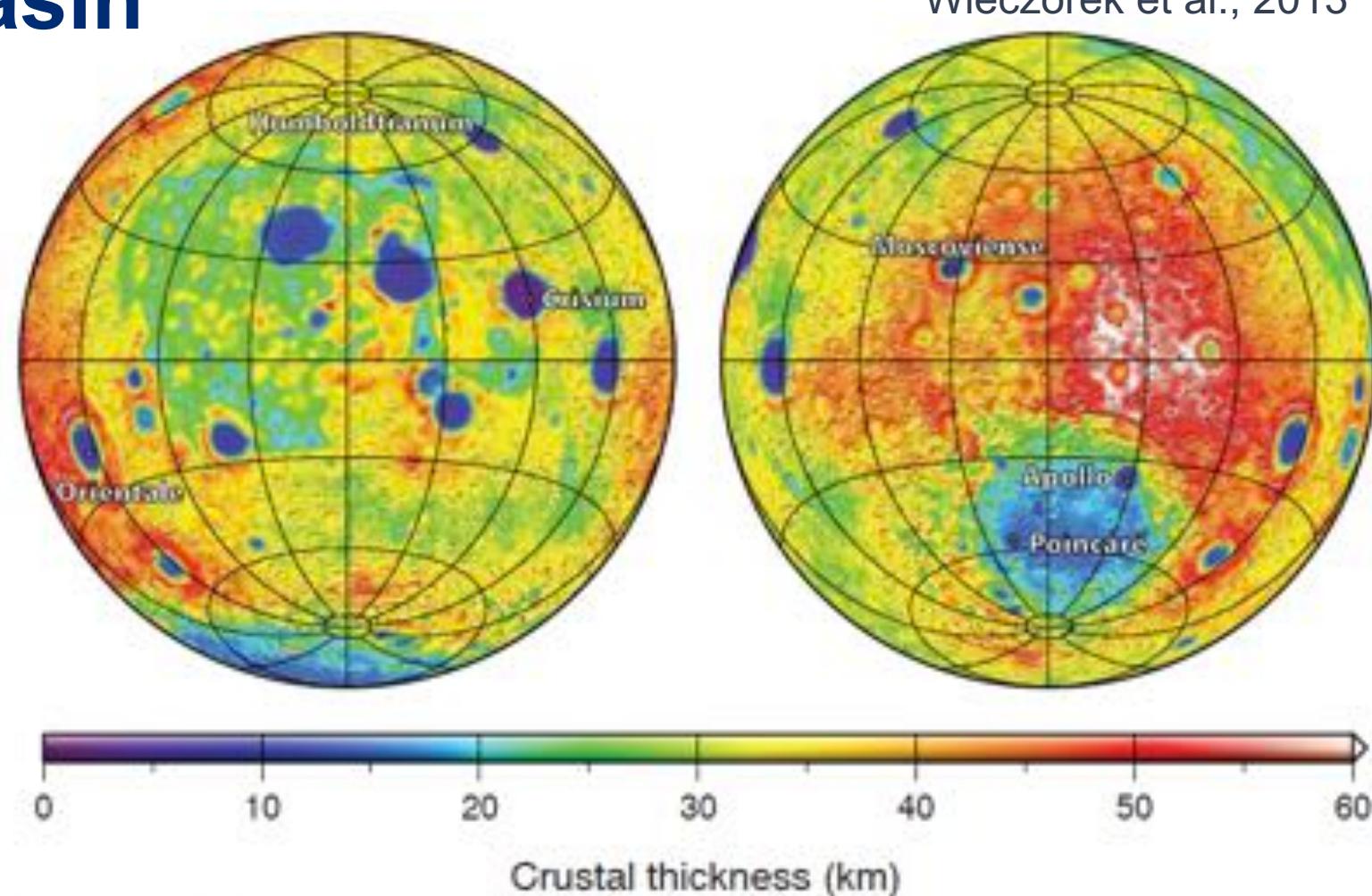


Fig. 3. Crustal thickness of the Moon from GRAIL gravity and LRO topography. With a crustal porosity of 12% and a mantle density of 3220 kg m^{-3} , the minimum crustal thickness is less than 1 km in the interior of the farside basin Moscovense, and the thickness at the Apollo 12 and 14 landing sites is 30 km. Image format is the same as in Fig. 1, and each image is overlain by a shaded relief map derived from surface topography.

Basin Formation

	Single Oblique Impact	Impact into Existing Basin	Double Impact	Oblique Impact into Crustal Anomaly
Partial Peak Ring	YES	YES	YES	YES
Elongated Basin Floor	YES	YES	YES	YES
Regional Slopes	YES	YES	YES	YES
Discontinuous Ejecta	YES	MAYBE	MAYBE	YES
Thin Crust	NO	YES	YES	YES
Gravity Anomaly	NO	YES	YES	YES
Mare Deposits	NO	YES	YES	YES

Summarized from Thaisen et al., 2011

Basin Ring Composition

- Peak Ring (Deepest)
 - Plagioclase
 - Olivine
 - Pyroxene
 - Mg Spinel
- Middle Ring (Shallowest)
 - Pure Crystalline Plagioclase (PAN)
- No highly silicic, evolved lithologies

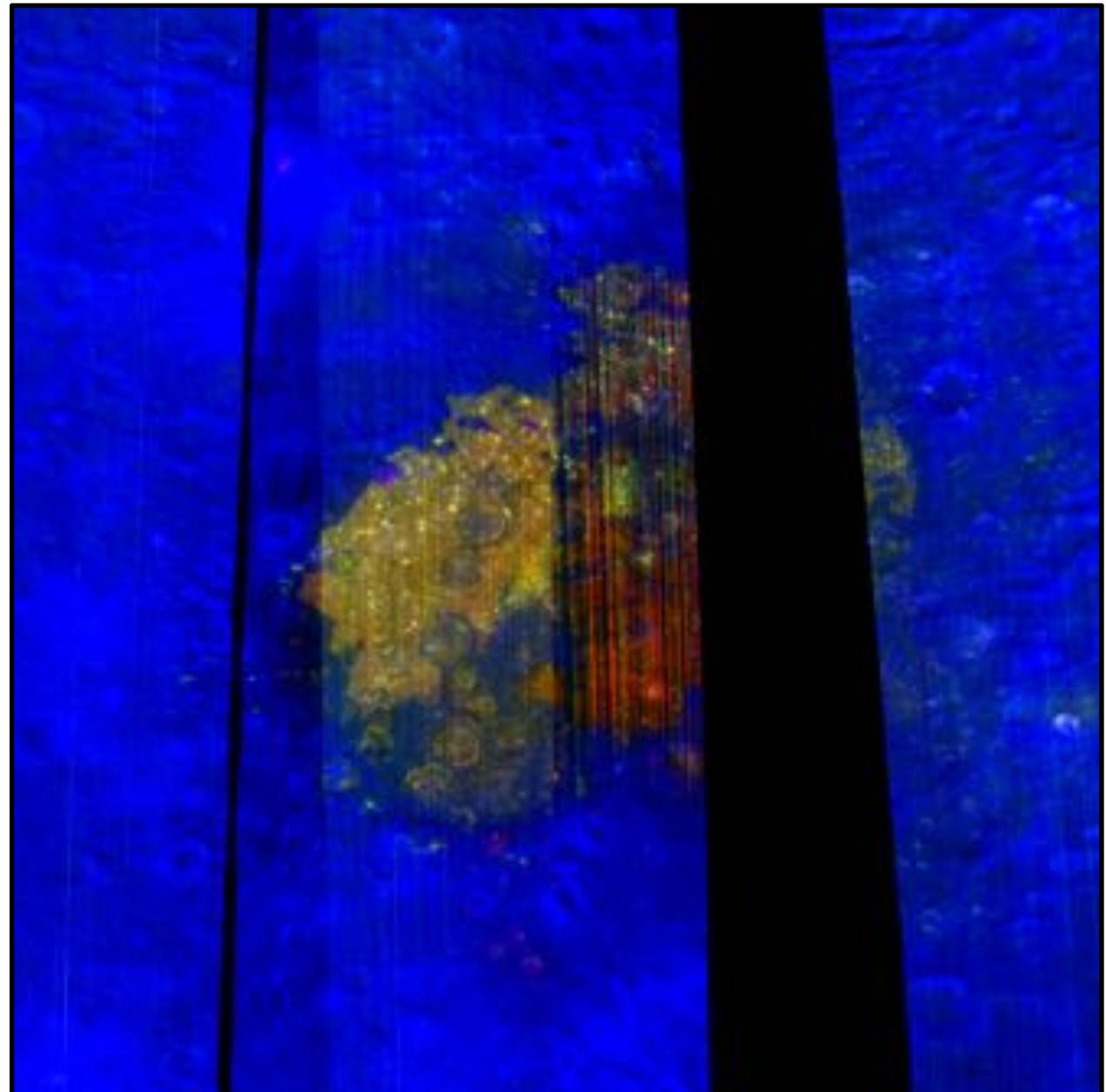
M3 Mosaic of Moscoviene Basin

Data from OP1B and OP2C1

Blue = reflectance at 1489 nm

Green = integrated band depth at 2000 nm

Red = integrated band depth at 1000 nm



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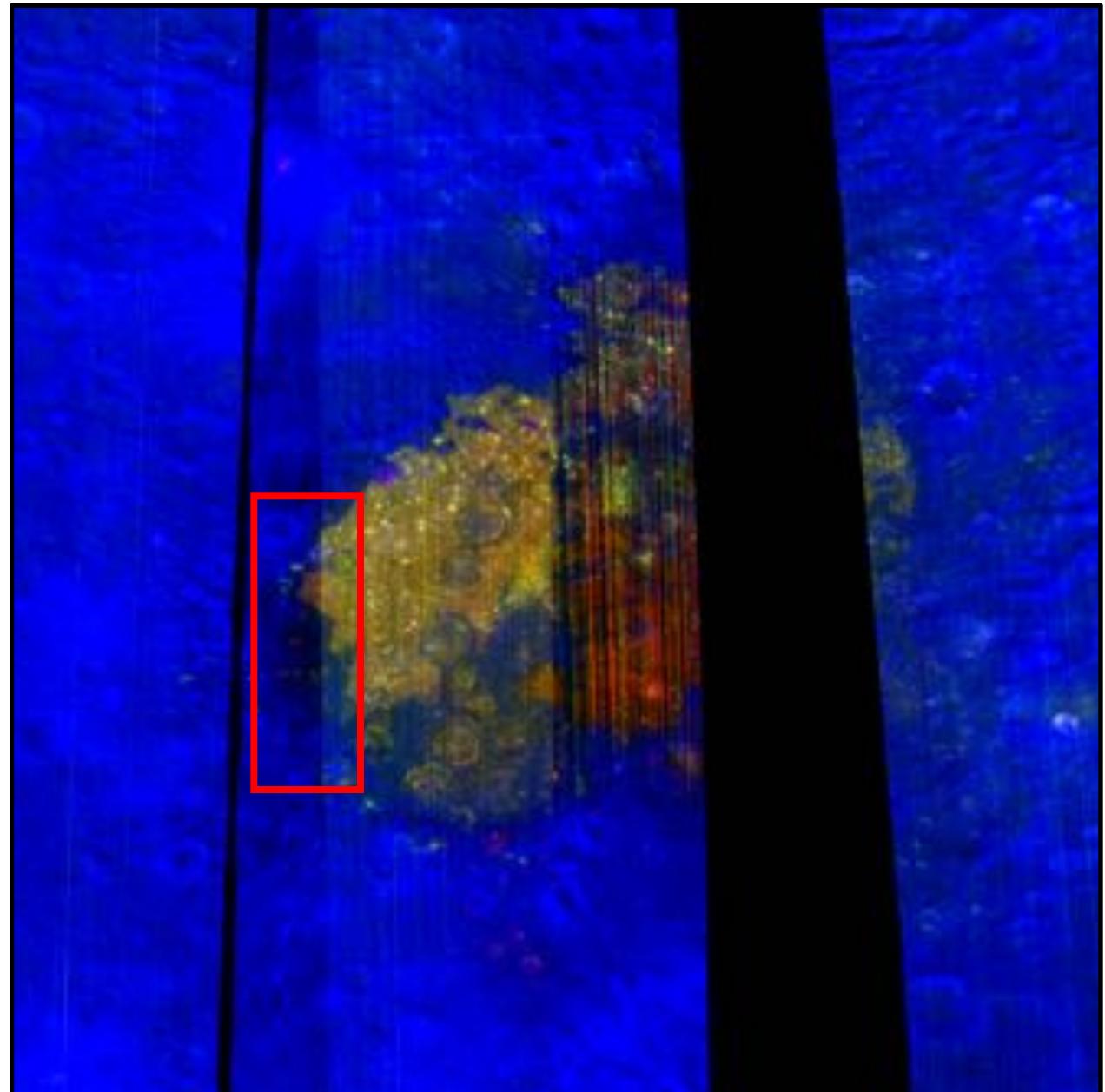
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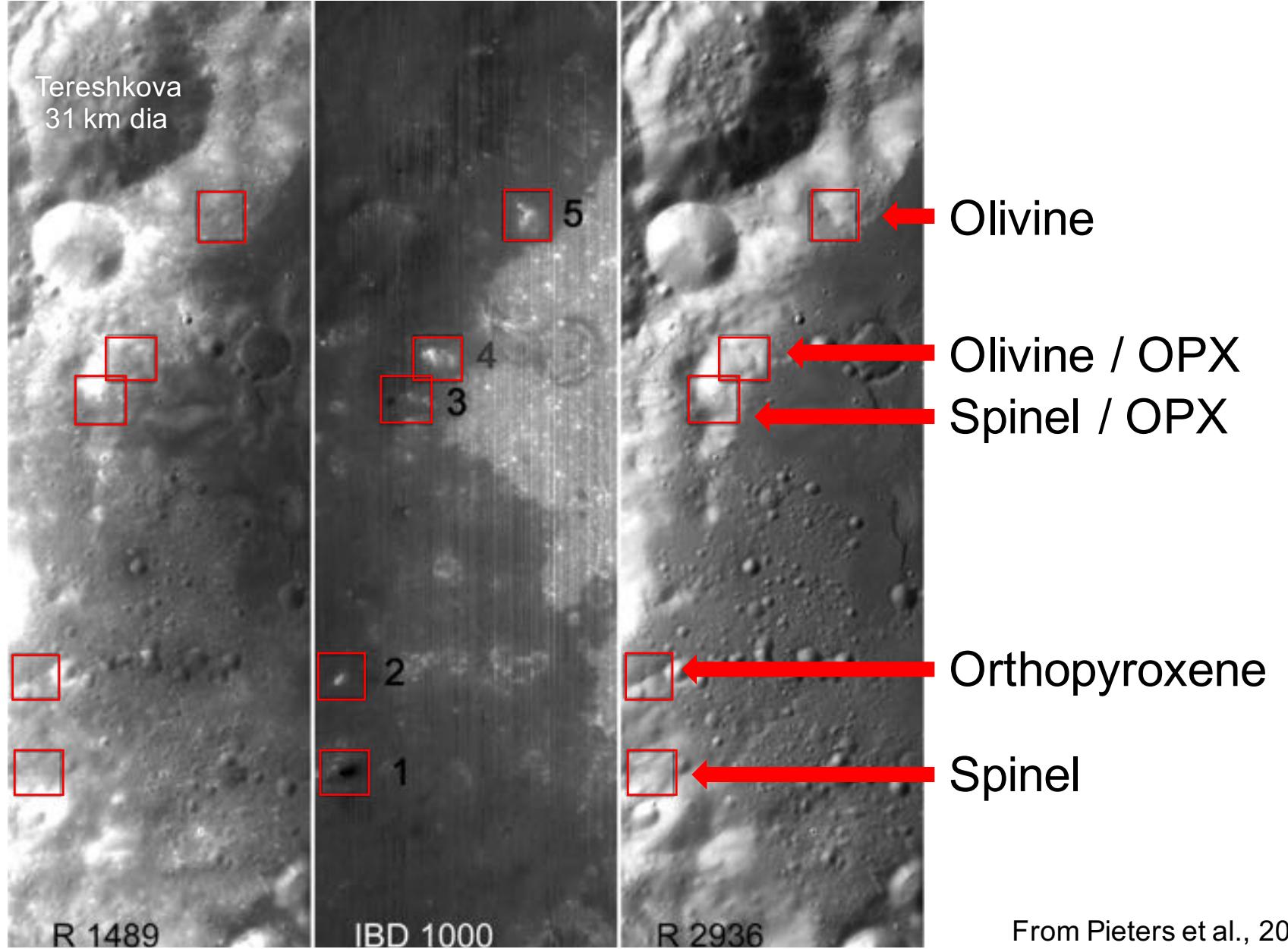
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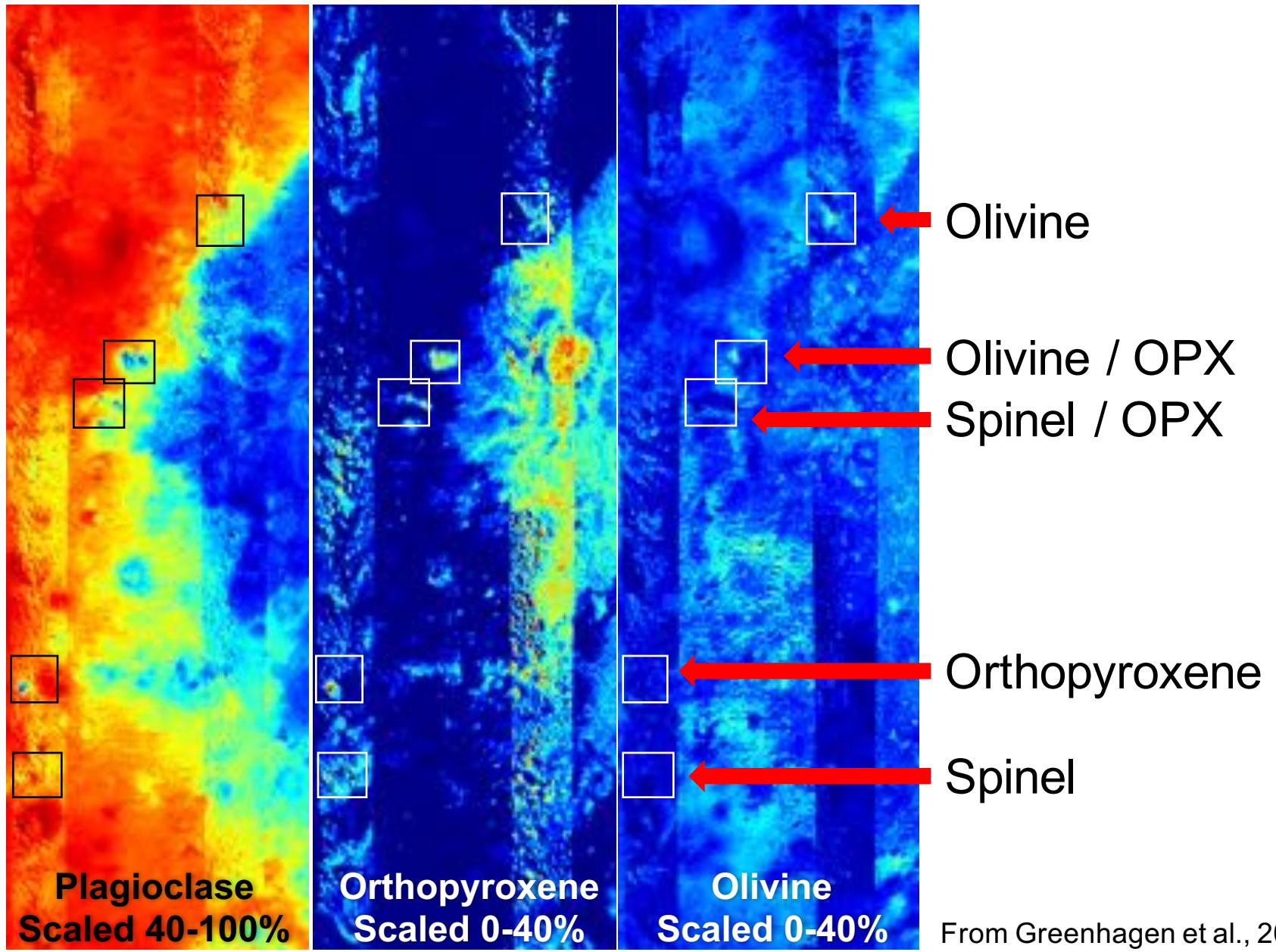
M³ OOS

- Orthopyroxene, Olivine, Mg-Al Spinel embedded in anorthosite-rich peak ring
- Big: km-scale deposits!
- OOS deposits are mature and undisturbed by recent impact craters
- Suggests origin as differentiated magmatic intrusions into the lower crust, perhaps near the crust/mantle boundary



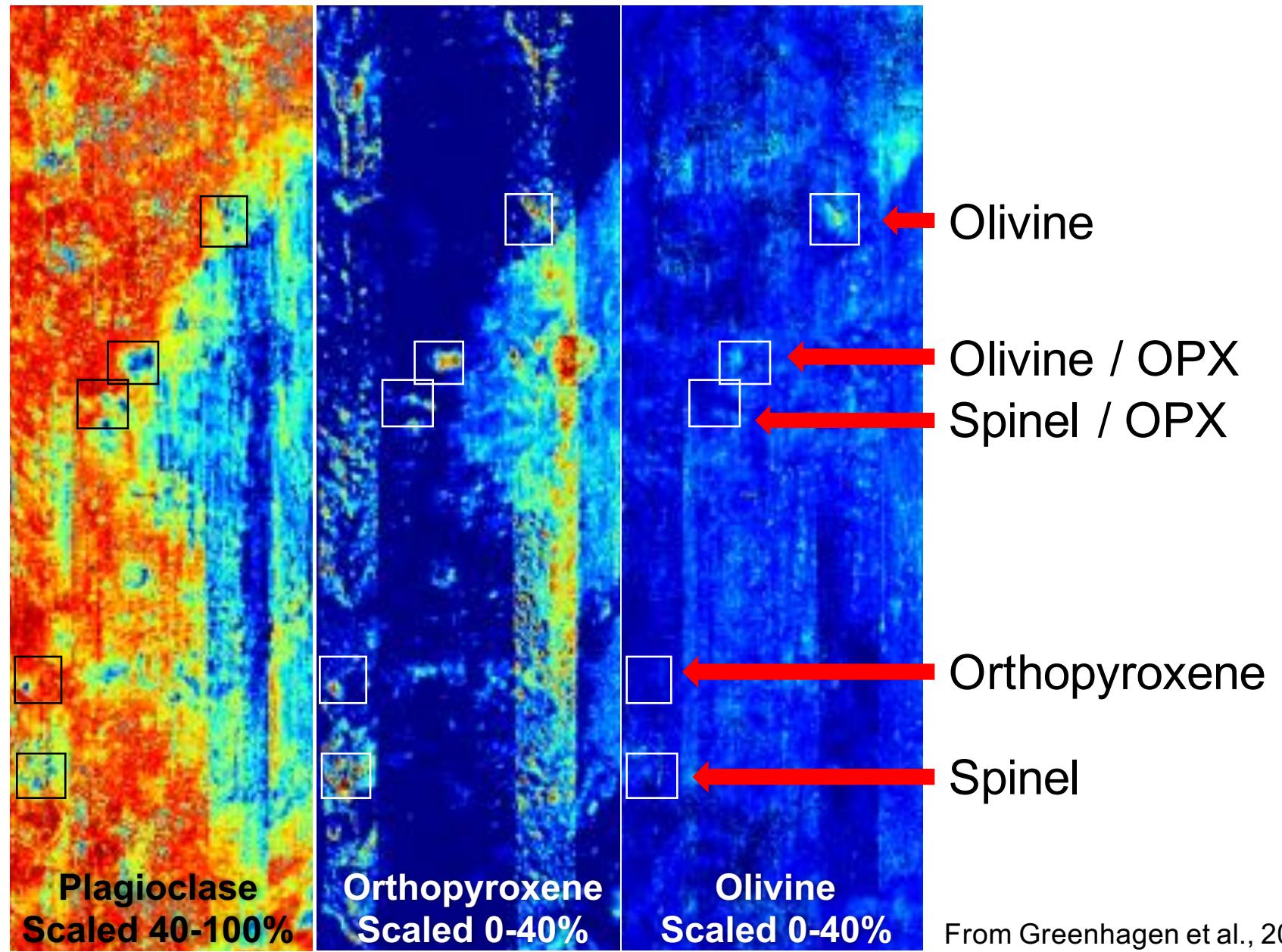
NIR Mineral Maps

- Mineral maps made from MI Vis and NIR multispectral data
- Data compared to large database of modeled spectra using MI-calculated FeO as constraining parameter (Lemelin et al., 2016)
- Based on methodology from Lucey et al., 2004



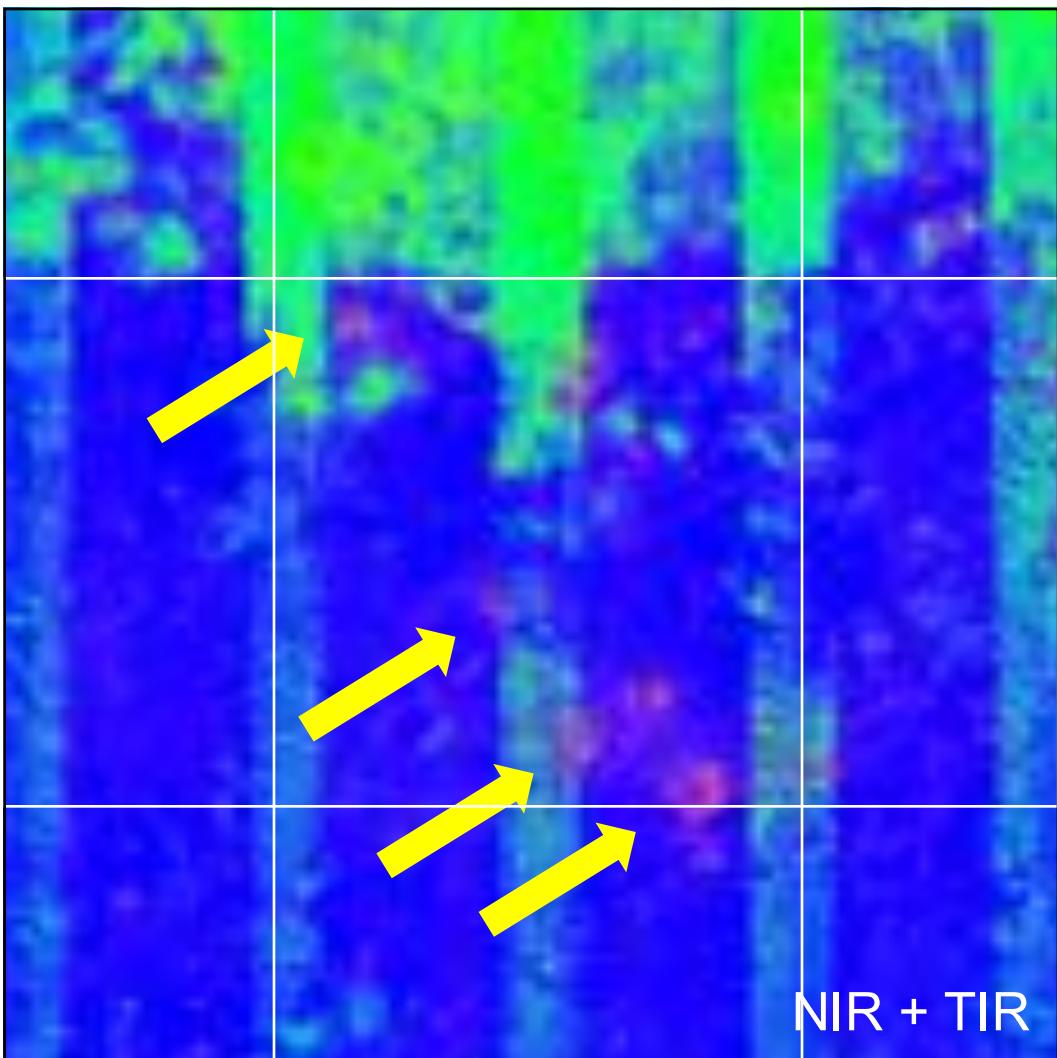
NIR+TIR Mineral Maps

- TIR is very sensitive to feldspar / mafic ratio
- Use TIR data from Diviner to constrain plagioclase abundance
- “Although the abundance of plagioclase is not well constrained within the OOS, the mafic mineral content is exceptionally high, and two of the rock types could approach pyroxenite and harzburgite in composition”
-Pieters et al., 2011

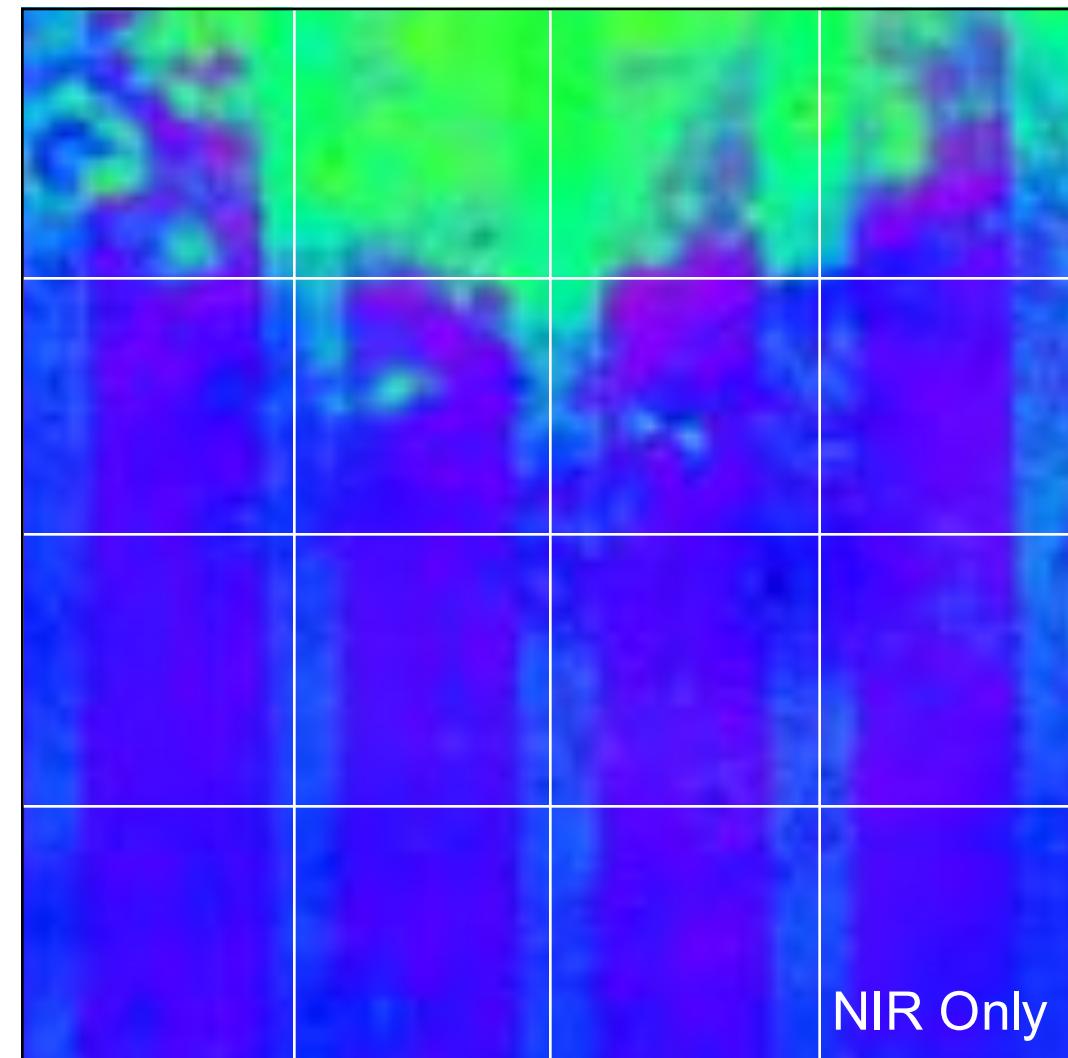


NIR + TIR Mineral Maps

From Greenhagen et al., 2014



Blue = plagioclase (0.4-1), Green = pyroxene (0-0.4),
Red = olivine (0-0.4)

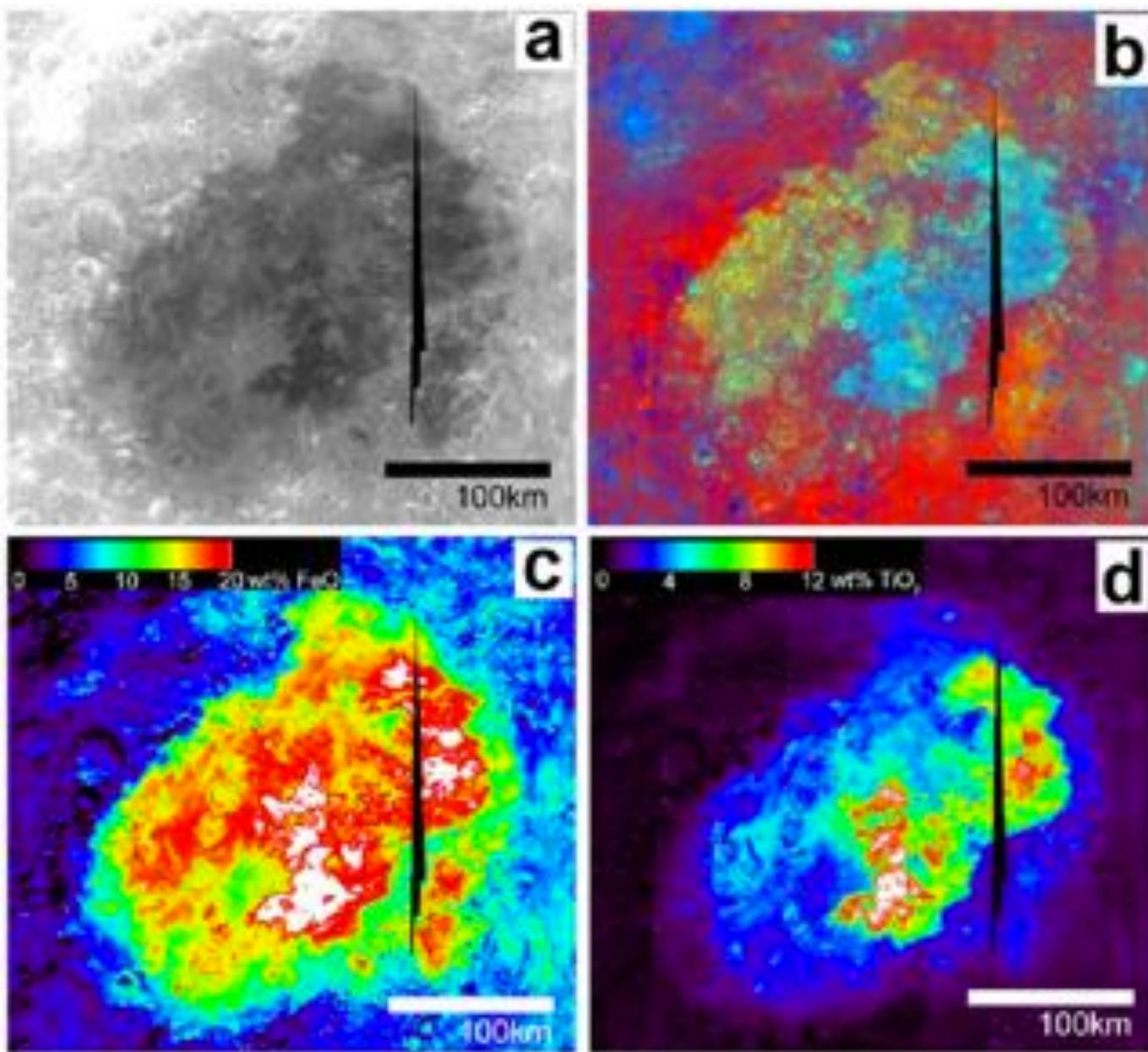


Help Identify potential targets

Mare Basalts: Composition

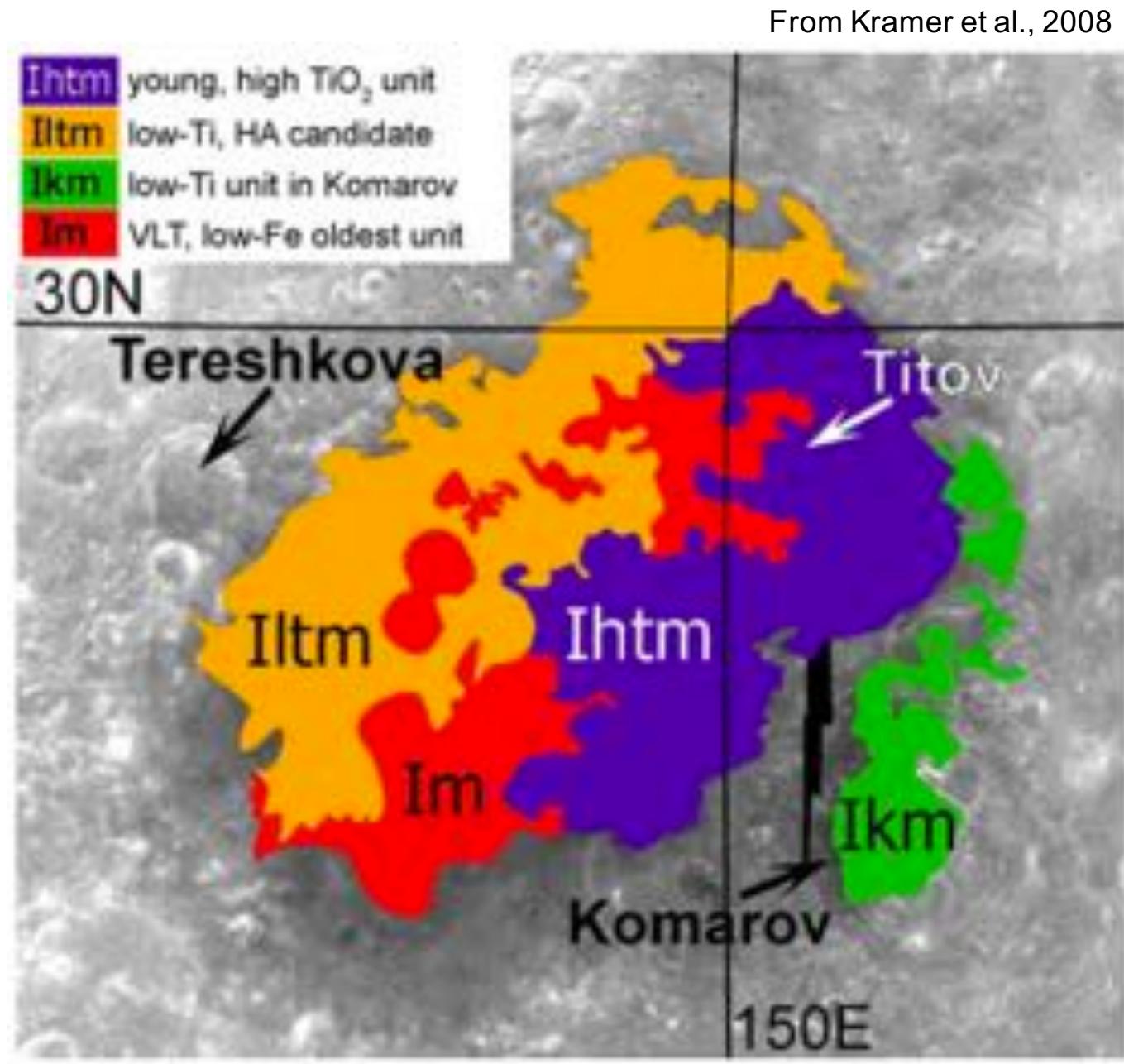
- Broad compositional diversity, readily distinguishable with UV/Vis/NIR imagery
 - Low/high FeO
 - Low/high TiO
 - Possible high alumina
- Kramer et al., 2008 system of naming deposits
 - Im = lowest FeO, very low Ti
 - Iltm = low Ti, possible high alumina
 - Ikm = Komarov unit, low to very low Ti
 - Ihtm = High Ti

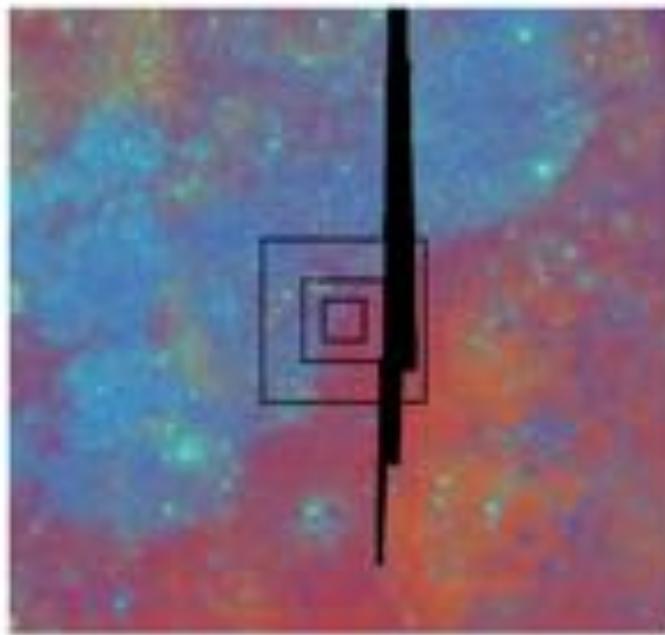
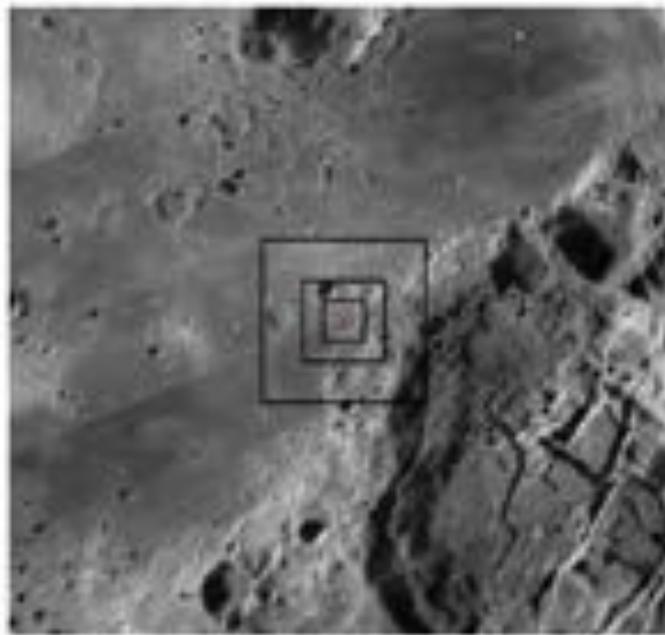
From Kramer et al., 2008



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Mare Moscovense

Location (longitude, latitude): 150.47, 26.19

Scientific Rationale:

Mare age and composition (e.g., far side mare)
Basin geology (e.g., inner ring)

Resource Potential:

High-Ti mare regolith

Operational Perspective:

Mare terrain

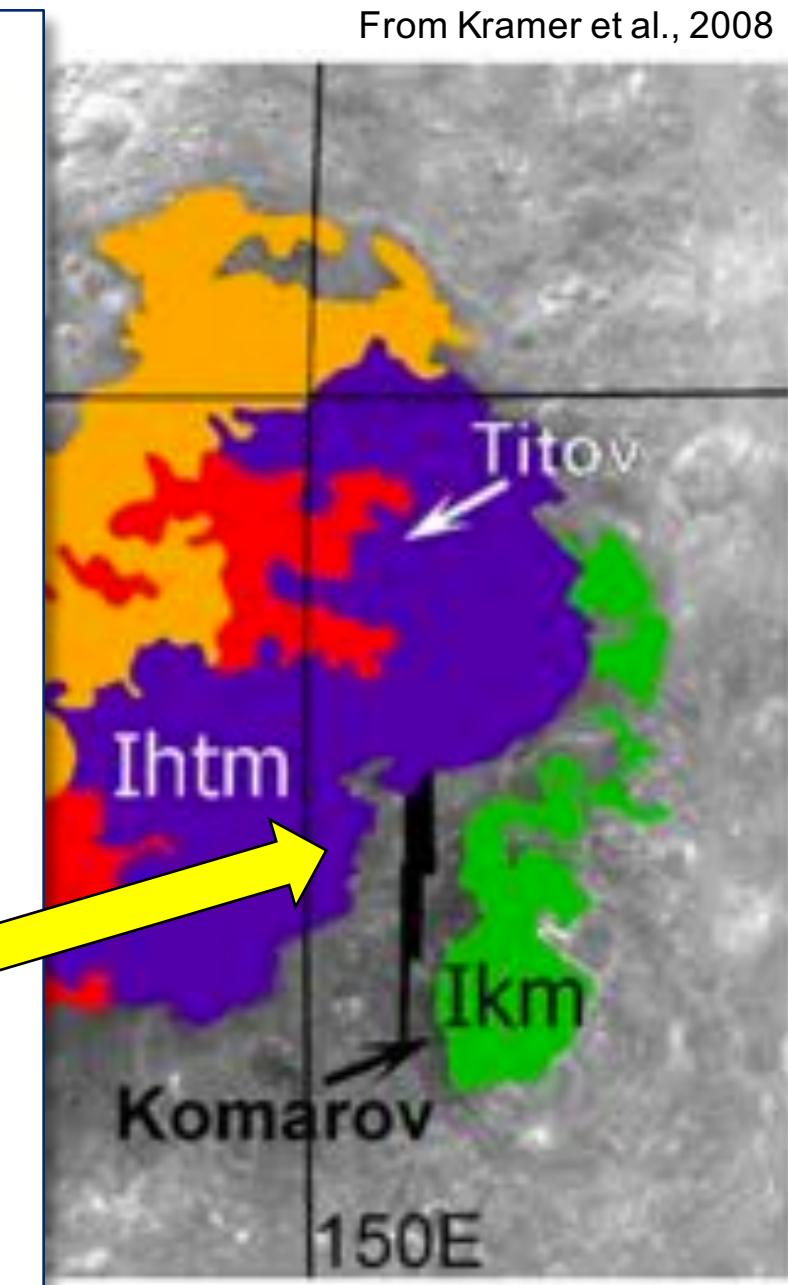
Highlands terrain

Far side location

NASA References:

Geoscience and a Lunar Base (1990)

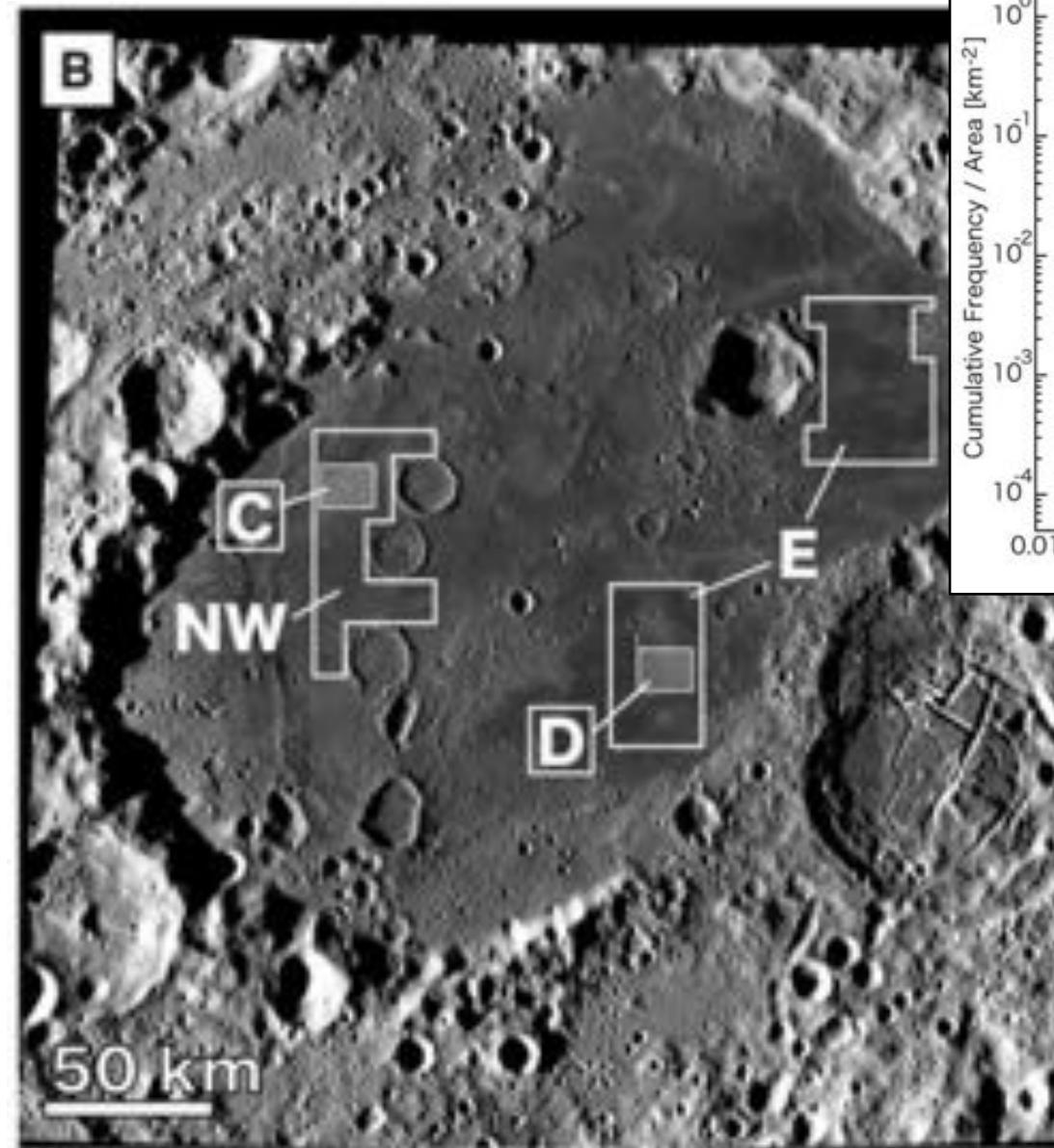
Other References:



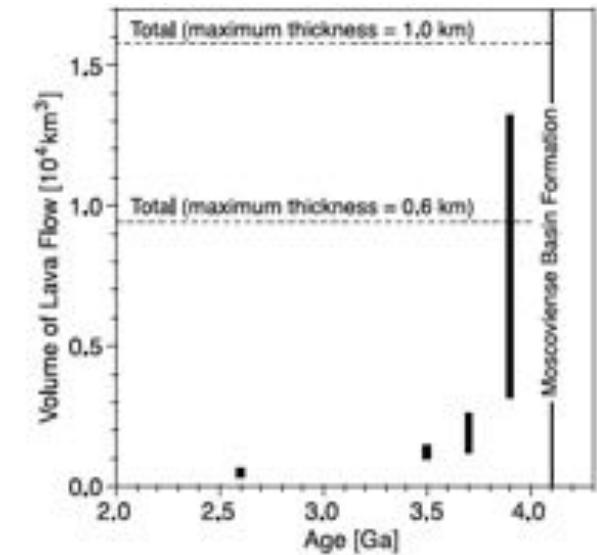
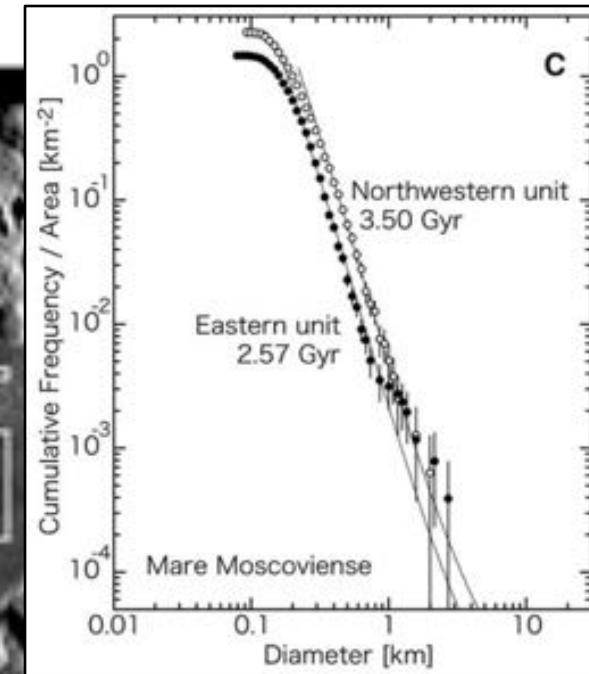
From Kramer et al., 2008

Mare Basalts: Age / Volume

- Deposits span 1.5 Ga
 - Im = oldest unit (~3.9 Ga)
 - IltM / Ikm = middle unit (3.5-3.7 Ga)
 - Ihtm = youngest unit (2.6 Ga)
- Youngest basalts have highest Ti content
- Correlation between estimated deposit volume and modeled age



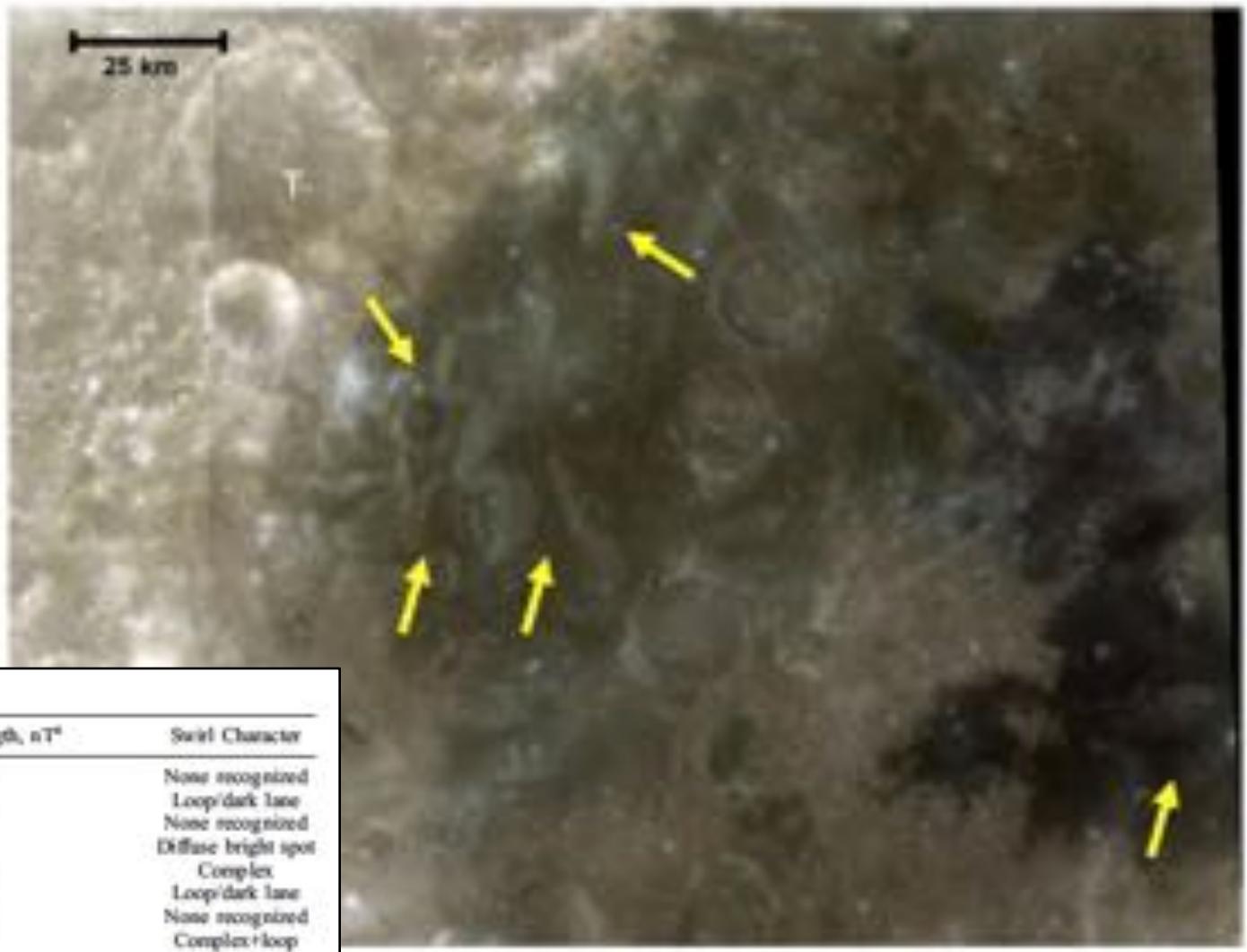
From Haruyama et al., 2009



From Morota et al., 2009

Swirls

- Weak magnetic anomaly
- Complex swirl features
- Most in older low Ti deposits
 - ~15 km from OOS!
- Some in younger high Ti deposits



From Blewett et al., 2011

Table 1. Lunar Magnetic Anomalies Examined in this Study

Location	Approximate Lat., Long.	Setting	Magnetic Anomaly Strength, nT ^a	Swirl Character
Abel	30°S, 90°E	Mare/highland	10 – moderate	None recognized
Airy	18°S, 3.25°E	Highland	13 – moderate	Loop/dark lane
Cassini	15°S, 51°E	Mare/highland	6 – weak	None recognized
Descartes	15°S, 52°E	Highland	24 – strong	Diffuse bright spot
Finsen	10.5°S, 16.5°E	Highland	11 – moderate	Complex
Gerasimovich	21°S, 236.5°E	Highland	28 – strong	Loop/dark lane
Hartwig	10°S, 280°E	Highland/mare	12 – moderate	None recognized
Hopmann	48.5°S, 160°E	Mare/highland	5 – weak	Complex+loop
Ingenii	33.5°S, 160°E	Mare/highland	20 – strong	Complex
Margolis	16°N, 88°E	Mare/highland	6 – weak ^b	Complex
Moscoviense	27°N, 145°E	Mare	4 – weak	Complex
NW of Apollo	25°N, 197.5°E	Highland	12 – moderate	Loop/dark lane
Reiner Gamma	7.5°N, 302.5°E	Mare	22 – strong	Complex
Rima Sirealis	8.5°N, 304.5°E	Mare/highland	8 – moderate	Loop/dark lane
Schäfer	40°S, 5°E	Highland	10 – moderate	None recognized

^aEstimated peak total field strength of magnetic anomaly at 30-km altitude: Weak, <7; moderate, 7–15; strong >15.

^bPoor coverage by Lunar Prospector magnetometer.

Merits of Moscoviense for Landed Missions

- A) Short term reconnaissance and/or surface science experiments (lunar day)
 - Any single site characterization
- B) Sample return
 - Basin impact melt
 - Lower crust mafics, including Mg-Al spinel
 - PAN / crystalline plagioclase
 - Farside mare basalts
- C) Long term monitoring (days, years)
 - Farside Swirls
- D) Regional roving experiments (ala MSL+)
 - Investigate the peak ring / western basin floor (swirls, pyroclastics)
 - Traverse the crust (peak ring to middle ring)
 - Traverse the range of mare deposits
- E) Technological demonstrations that feed forward
 - Traversing sloped surfaces
 - Roving / sample caching
 - Sample return
 - Teleoperations from DRO station
 - Farside observatories
- F) Technological demonstrations for ISRU
 - High Ti basalts
 - Oxygen yields from different basalts / pyroclastics

